Effects of near Field Pyroshock on the Performance of a Nitramine Nitrocellulose Propellant

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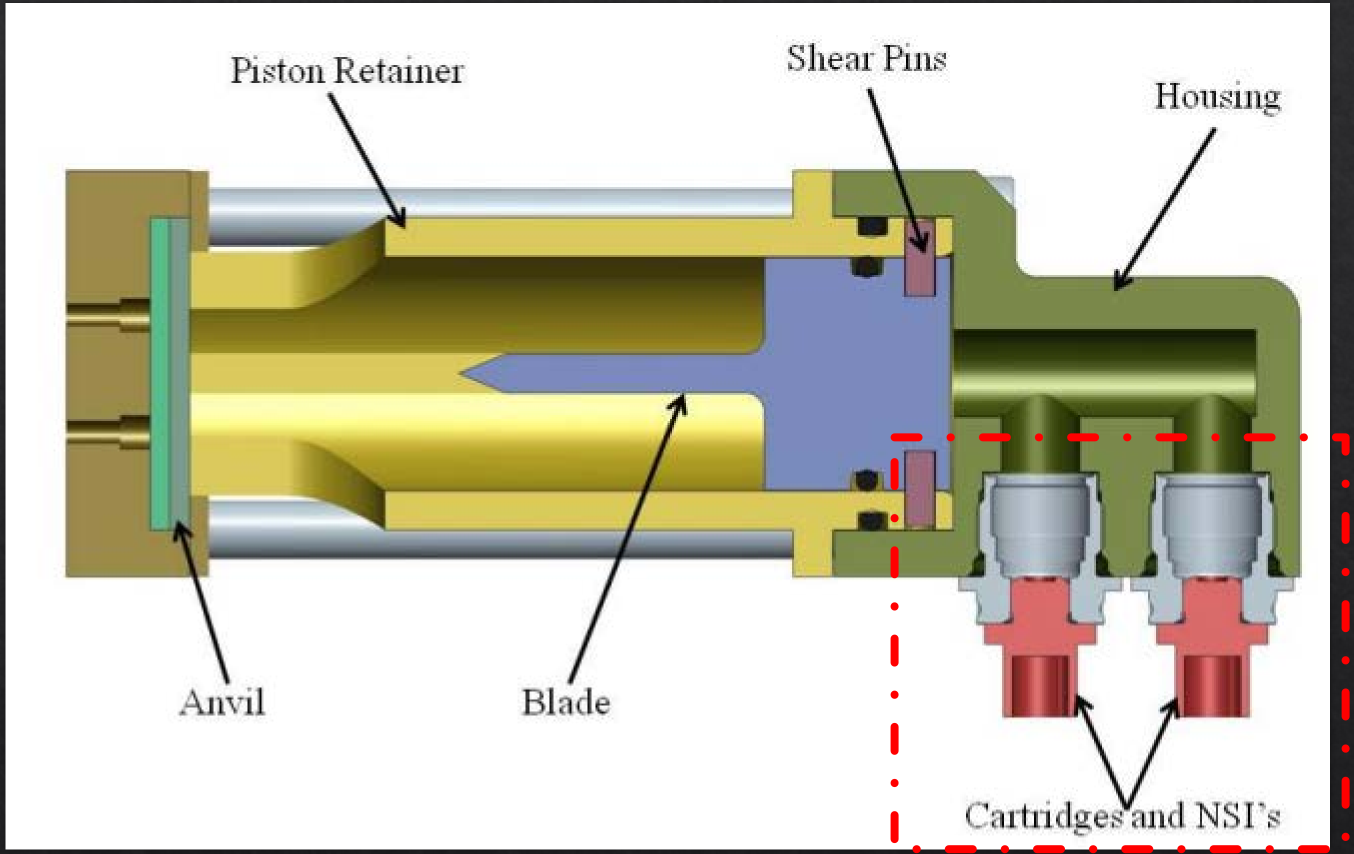
Report Summary

- The purpose of this study is to investigate the effects of a pyroshock environment on the performance characteristics of a propellant used in pyrotechnic devices such as guillotine cutters. A heritage pressure cartridge assembly which uses a nitramine nitrocellulose propellant with a known performance baseline will be exposed to a near field pyroshock event. The pressure cartridge will then be fired in an ambient closed bomb firing to collect pressure time history. This data will be compared to the base-line data to evaluate the effects of the shock on the performance of the propellant.

Pyrotechnic Pressure Cartridge

- Used in many pyrotechnic systems:
  - Gas generators
  - Guillotine cutters
  - Mechanical actuators
  - Pyro-valves
- Typically initiated with an electrical initiator (sometimes with detonating cord)
  - NASA Standard Initiator NSI
  - Flexible Confined Detonating Cord Assembly (FCDCA)
  - Confined Detonating Cord (CDC)

Example Guillotine Cutter



Orion Riser Cutter Components

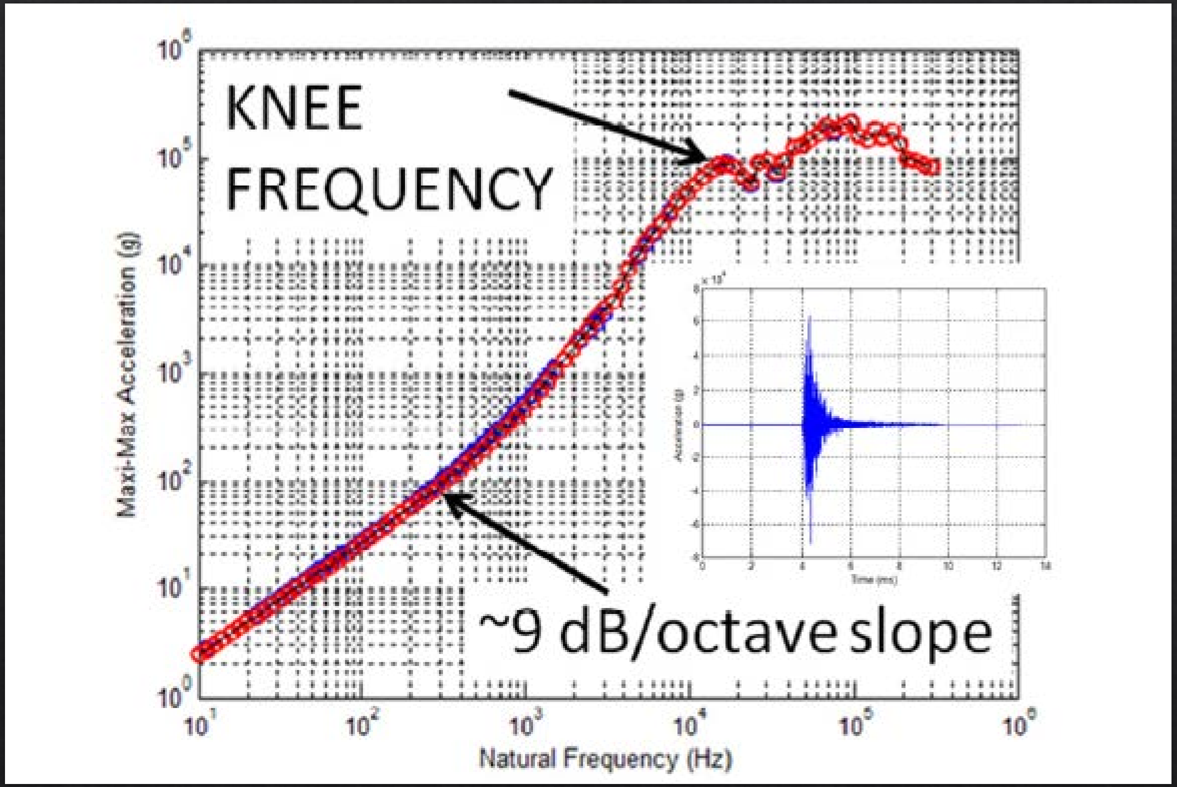
Retrieved from Orion Parachute Riser Cutter Development (ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20100039628.pdf)

Pyroshock

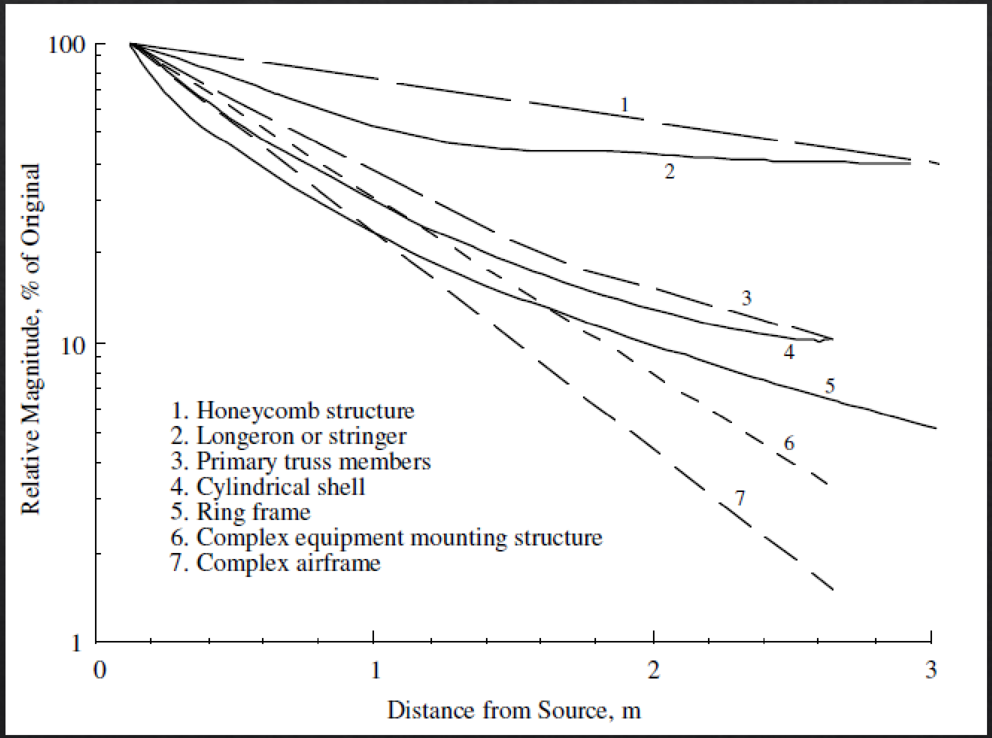
- Per Harris' Shock and Vibration Handbook pyroshock is, "The response of a structure to high-frequency (thousands of hertz) high-magnitude stress waves that propagate throughout the structure as a results of an explosive device."
- Three regions of pyroshock
  - Near-field
  - Mid-field
  - Far-field

Document	Region	Acceleration Amplitude (*g*)	Frequency (Hz)	Distance from Source	
				Intense Source	Mild Source
NASA STD 7003	Near-field	>5000	>100 k	<6 in.	<1 in.
	Mid-field	1000–5000	>10 k	6–24 in.	1–6 in.
	Far-field	<1000	<10 k	>24 in.	>6 in.
IEST-RP-DTE032 and MIL-STD-810G, Method 517	Near-field	>10,000	≥10 k		
	Mid-field	<10,000	3 k–10 k		
	Far-field	<1000	≤3 k		

Pyroshock Environments



Typical Near-Field Acceleration Time History
and Positive and Negative Shock Response Spectrum



Peak Pyroshock Response versus
Distance from Pyrotechnic Source

Figures retrieved from NASA-STD-7003A Pyroshock Test Criteria

Pyroshock Testing

- Time acceleration history measured at the interface of test article via shock accelerometers and or laser vibrometers.
- Acceleration history used in Shock Response Spectrum Analysis
  - Peak acceleration response for a specific natural frequency based off of a frequency range is calculated for both the positive and negative directions in the acceleration time history
  - Model built upon a single degree of freedom system with infinite natural frequencies
  - Natural frequencies are spaced as a proportional bandwidth split and for this test were spaced on a 1/6 octave

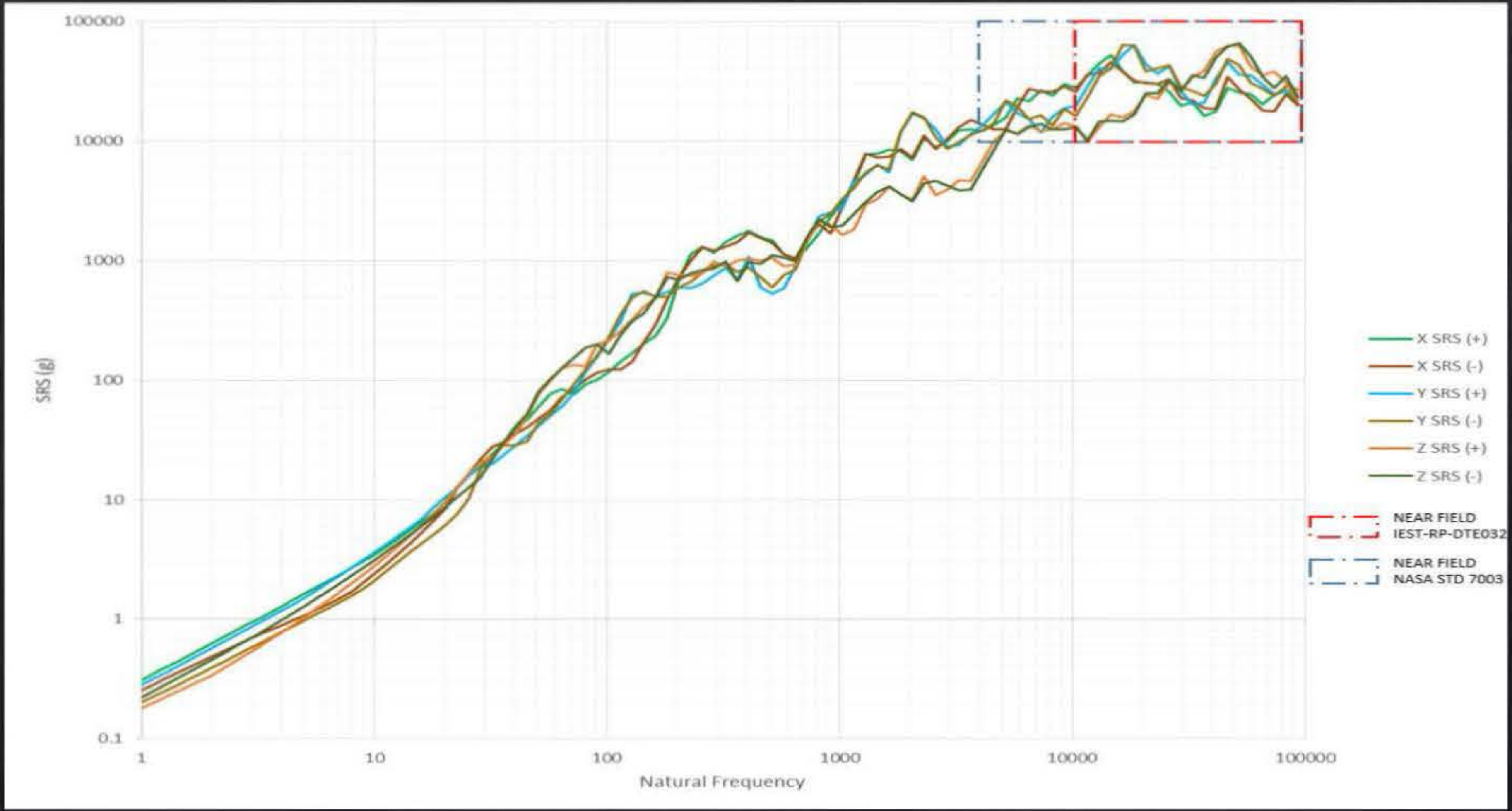
Damage from Pyroshock

- Shock source created by functioning of other pyrotechnic systems
  - Fairing separation
  - Guillotine cutters
  - Frangbile joints and frangible nuts
- Near-Field propagates as compressive wave
- Shock propagates along structure to nearby devices
- Highly Transient on the order of 1 ms to 20 ms
- Large oscillatory accelerations and high velocity change
  - Structural failure
- High frequency response known to cause electronic failures
  - Failure of solder joints

Propellant Susceptibility to Pyroshock

- Did not expect the compressive wave to adequately transmit into propellant grain
  - Loose load with housing
- Fracture in grain expected from housing velocity changes
  - Impact of propellant grain to housing walls and other grain
- Impacts cause of brittle failure
  - Increased strain rate in grain will push from ductile to brittle transition
- Even plastic yield of grain can increase performance
  - Mechanically enhance reactivity from lattice deformation

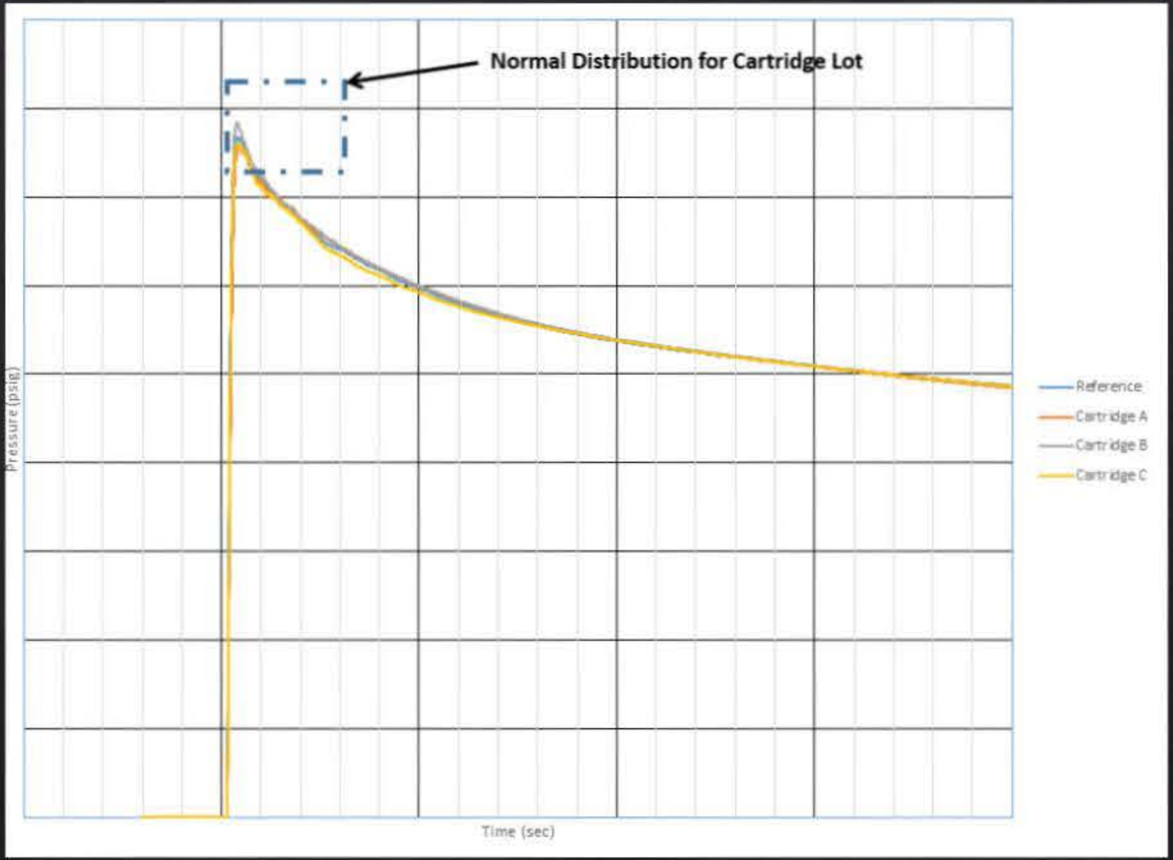
Pyroshock Test Results



Closed Bomb Testing

- Used to characterize propellant performance
  - Peak pressure
  - Time to peak from first indication of pressure
- Constant volume vessel
  - Volume verified prior to testing
- Ported for pressure cartridge output and pressure transducers
  - Primary and Secondary pressure transducer to measure pressure time history
  - High impedance charge mode piezo-electrics designed specifically for ballistics measurements

Closed Bomb Firing Results



Summary of Results

- The resultant data from the closed bomb firings did not provide sufficient evidence to support the theorized increased performance of a nitramine nitrocellulose propellant subjected to pyroshock. The data did not show any clear indication of a change in the propellant performance. Given the relatively small sample size it is reasoned that the peak pressures and time to peak pressure remained within the normal distribution for this specific lot of cartridges. The variability from each closed bomb firing is minimal and well within the pass fail region. Only one of the cartridges exhibited a higher peak and time to peak than the reference cartridge. While potentially an indication of higher performance as stated previous this change is minimal and cannot be considered indicative of a change to the propellant.